Supplementary/supporting information

Morphology of CdSe/ZnS core/shell QDs coated on textured surface with SiN_X film of a p-type silicon solar cell: The cross-sectional x-TEM image in Supplementary Fig. 1a exhibited the surface morphology of 0.3 wt% green-light emitting CdSe/ZnS core/shell. Core/shell QDs were well dispersed and coated on the surface of a {111} SiN_X anti-reflective layer surface of a p-type silicon solar cell. However, there were fewer coated core/shell QDs at the summit of the {111} pyramid surface than at the valley of the {111} pyramid surface. The x-TEM image in Supplementary Fig. 1b shows the surface morphology of 1.0 wt% green-light emitting CdSe/ZnS core/shell. Core/shell QDs were well dispersed and coated on the surface of the {111} SiN_X anti-reflective layer in a p-type silicon solar-cell. However, the coating thickness of core/shell QDs at the summit of the {111} pyramid surface was less than that at the valley of the {111} pyramid surface. The comparison of Supplementary Fig. 1a with 1b indicates that the coated amount of core/shell QDs on the surface of the {111} SiN_X anti-reflective layer increased with the core/shell QD concentration (wt%). Thus, the intensity of the emitted visual light from green-light emitting CdSe/ZnS core/shell ODs increased with the QD concentration (wt%).

Proof of energy-down-conversion process via blue-, green-, and red-light CdSe/ZnS core/shell QDs: For all core/shell QDs, cadmium oxide, oleic acid, zinc acetate, and 1-octadecene were mixed at room temperature and heated up to 150°C under vacuum. Subsequently, the distilled mixture chemical was heated up to 310°C, and then selenium and sulfur solutions were rapidly injected and reacted for 15 min. The difference between blue-, green-, and red-light emitting CdSe/ZnS core/shell QDs was an injection sequence of selenium and sulfur solution. The

sulfur solution was first injected at 310°C and then followed by the selenium solution for blue-light emitting CdSe/ZnS core/shell QDs, while the selenium solution was first injected at 310°C and then followed by the sulfur solution for red-light emitting CdSe/ZnS core/shell QDs. However, both selenium and sulfur solutions were simultaneously injected at 310°C for greenlight emitting CdSe/ZnS core/shell QDs. After the reaction, the solutions dispersed with core/shell QDs was cooled-down at room temperature and then centrifuged with ethanol. Finally, the precipitated QDs were re-dispersed with chloroform.

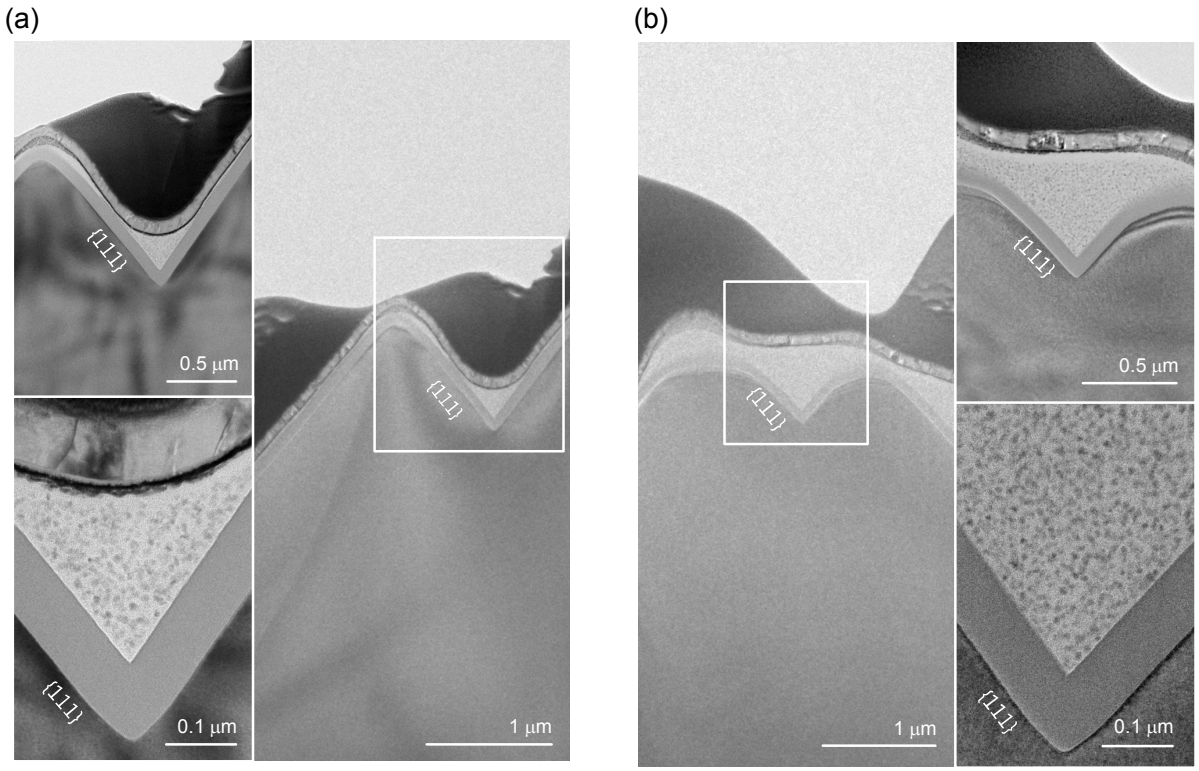
To confirm the energy-down-conversion of core/shell QDs, the UV lights with 254 and 365 nm wavelengths were illuminated in the solutions dispersed with three types of core/shell QDs. Blue-, green-, and red-light emitting CdSe/ZnS core/shell QD emitted the 470 and 473 nm blue light, 558 nm green light, and 605 and 606 nm red light, respectively, when both 254 and 365 nm UV-light absorption were illuminated in the solutions dispersed with QDs, as shown in photographs of quartz-cuvette in Supplementary Figs. 2a-c. Note that for all core/shell QDs the emitted light intensities from 254 nm UV-light absorption were higher than those from 365 nm UV-light absorption. These results presented clear evidence of energy-down-shift once again since three types of core/shell QDs absorbed UV wavelength lights and emitted visible wavelength lights. To characterize the energy-down-shift of core/shell QDs more detailed, we investigated the absorbance and photo-luminescence (PL) signal for three types of core/shell QDs as a function of wavelength. Green-light emitting CdSe/ZnS core/shell QDs absorbed lights from ~ 600 to 250 nm in wavelength. Their absorbance was increased and red-shifted when the QD concentration increased, as shown in Supplementary Fig. 2a. 0.5 wt% green-light emitting CdSe/ZnS core/shell QDs emitted both 524 and 559 nm PL peak signals. The PL signal intensity for 559 nm (7,350 arb. Unit) was 2.1 times higher than that for 524 nm (3,500 arb. unit). In

addition, red-light emitting CdSe/ZnS core/shell QDs absorbed lights from ~ 700 to 250 nm in wavelength, as shown in Supplementary Fig. 2b. Their absorbance was also increased and red-shifted when the QD concentration increased. Moreover, 0.5 wt% red-light emitting CdSe/ZnS core/shell QDs emitted the 644 nm PL peak-signal with the intensity of 6,000 arb. unit. Blue-light-emitting CdSe/ZnS core/shell QDs absorbed lights from ~ 500 to 250 nm in wavelength, as shown in Supplementary Fig. 2c. Their absorbance was increased and red-shifted when the core/shell QD concentration increased. 0.5 wt% blue-light emitting CdSe/ZnS core/shell emitted the 453 nm PL peak-signal with the intensity of 2,300 arb. unit. However, the sequence of wider absorption wavelength was followed by red-, green-, and red-light emitting CdSe/ZnS core/shell QDs, as can be seen by comparing Supplementary Figs. 2a-c. The correlation between the absorbance and PL signal obviously proved that three types of core/shell QDs absorb UV lights and emit their specific visible lights through energy-down-shift process.

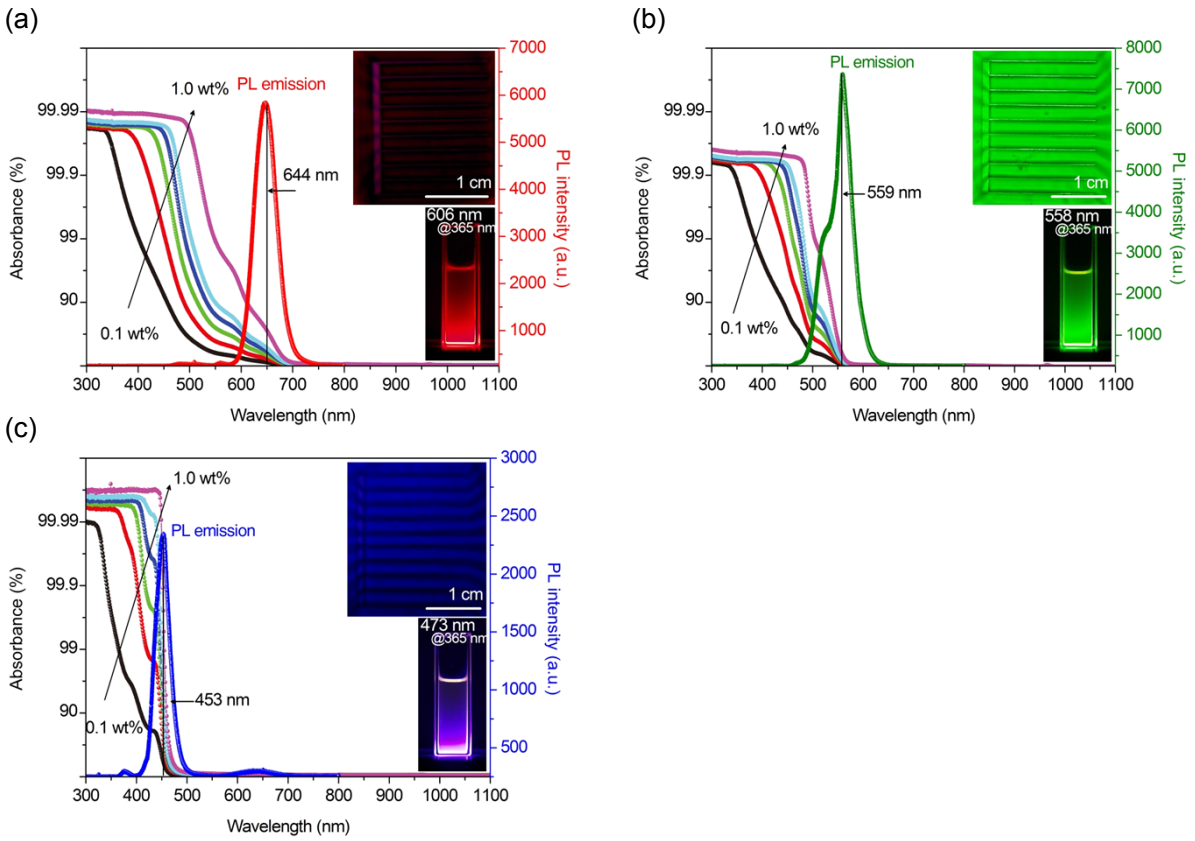
Dependencies of the absorption, PL intensity, and emitted light intensity of the thin film spin-coated with the QDs on the QD type and concentration

For all QD types, the emitted light intensity after illuminating the UV light with 365-nm in wavelength increased with the QD concentration (wt%). In particular, the sequence of higher emitted light was followed by green-light emitting CdSe/ZnS QD, red-light emitting CdSe/ZnS QD, and CdSe QD.

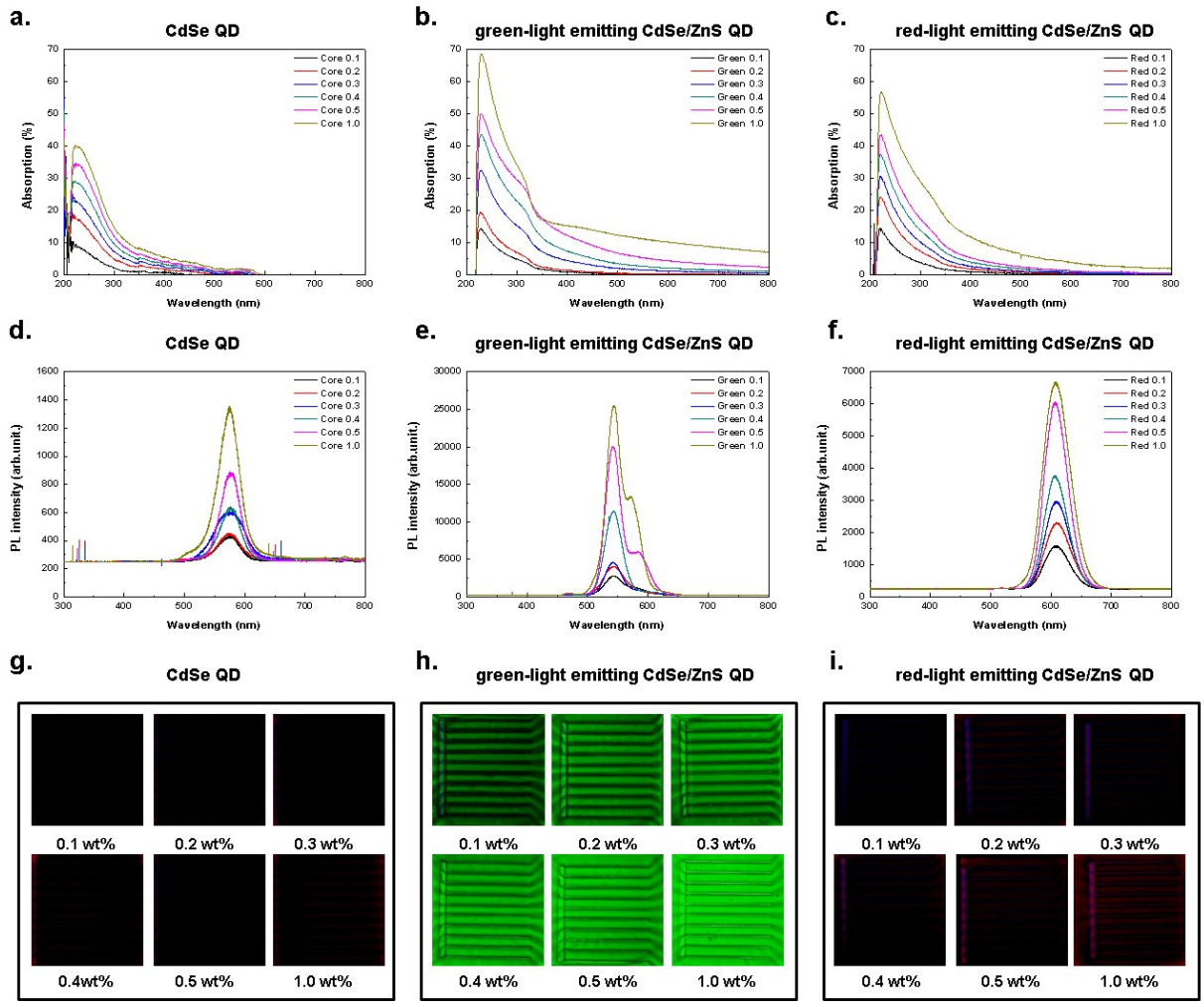
SUPPLEMENTARY FIGURES



Supplementary Figure 1. **Surface morphology of a p−type silicon solar cell coated with green−light emitting CdSe/ZnS QDs.** Core/Sell QDs were spin−coated at 1,000 rpm for 60 s on a {111} SiN_X anti−reflective layer. The x−TEM image was observed at 200 keV in acceleration voltage. **a**. 0.3 wt% and **b**. 1.0 wt% coated CdSe/ZnS QDs.



Supplementary Figure 2. **Absorbance, photo–luminescence, photography emitting light of the QD solutions, and photography emitting of p–type solar–cell surface for three types of QDs**. The absorbance of the QD solutions were measured at 0.1, 0.2, 0.3, 0.4, 0.5, and 1.0 wt%. The photo–luminescence of the QD solution spin-coated on the glass like a thin film was obtained at 0.5 wt%. The emitting light photography of the solar-cell surface were taken after the UV light illumination with 254 and 365-nm in wavelength. **a**. Blue–light emitting CdSe/ZnS core/shell QDs. **b**. Green–light emitting CdSe/ZnS core/shell QDs. **c**. Green–light emitting CdSe/ZnS core/shell QDs.



Supplementary Figure 3. **Absorption, photo–luminescence, photography for spin-coated thin films of three types of QDs**. Absorption and PL intensity of the thin film of the QDs spin-coated were measured as a function of the QD concentration and the wavelength. The photographies of the solar-cell surface spin-coated with the three types of QDs were obtained after the UV light illumination with 365-nm in wavelength. **a-c.** absorption of three types QDs. **d-f**. photo-luminescence of three types QDs. **g-i.** photography of three types QDs.